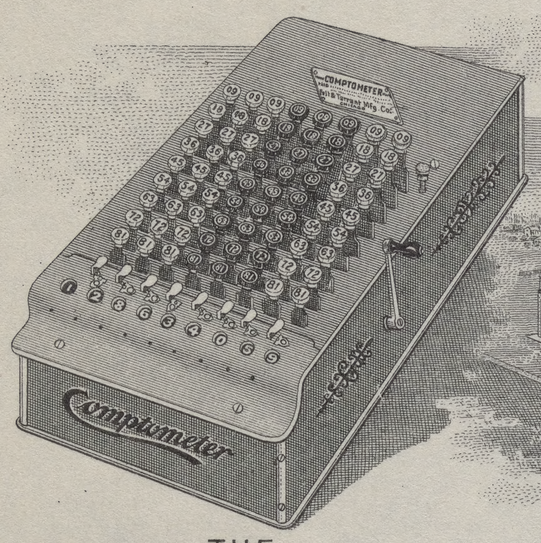
LITHOGRAPHED IN U.S.A.



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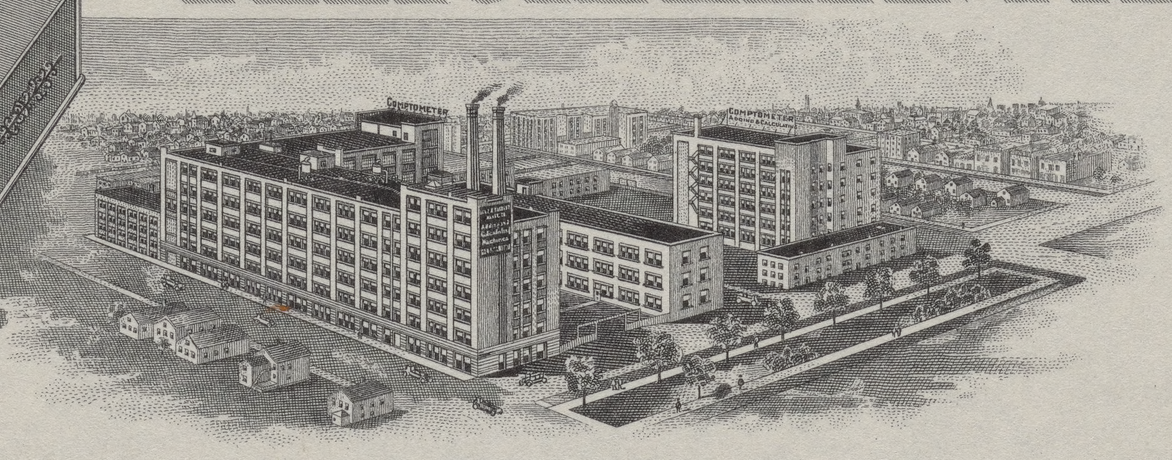

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THE Comptometer REG. TRADE MARK
PERFORMS EASILY EVERY ADDITION AND CALCULATION FOUND IN BUSINESS

February 25, 1929.

Mr. L. Leland Locke,
950 St. Johns Place,
Brooklyn, N. Y.

Dear Friend Locke:-

Your letter of the 17th received, but owing to pressing matters I have been unable to answer it until now.

I certainly would be very much pleased to accept your kind offer of loan of your photographs of the Wiberg machine. All I have regarding the Wiberg machine are a few abstracts which I have gleaned from articles on calculating machines. I am enclosing copies of these abstracts, thinking that perhaps there may be something in them that you haven't a record of.

Your article on the Grant machine will certainly be very interesting, and I shall be very much pleased to receive a copy of the printed article when you have it finished.

Your advice that you are translating Pascal's "Avis" from Professor Smith's Source Book is quite interesting, although I must admit I am ignorant of the subject it pertains to, other than, if I can remember my Latin, "Avis" means "something to do with flying". Should be interested to know more about this book of Professor Smith's when you have time.

I note your kind offer of photos of the Warren machine, and may avail myself of this opportunity some time. I have not, however, had a chance to give any time to my book since last August, and it looks as if it will be next August before I get a chance to work on it again.

I want to show you that I am still keeping you in mind with regard to the photos that I have spoken of in former letters, but we have been very busy and haven't been able to put them through for printing.

Very sincerely yours,

JAVTurck/GL

FORM 23A

MONROE
REG. TRADE MARK

MEMORANDUM

Date May 21, 1930

Subject Scheutz Calc.Mach.Article from "English Life Table"

To Mr. L.Leeland Locke
950 St.John's Pl.
Office Brooklyn, NY

From G.C. Chase
Office Orange, NJ

NOTE: To insure against any omissions in reply and to facilitate accuracy in filing please cover but ONE subject on this sheet. Use short form (23B) where possible.

Dear L^3:

We are returning herewith the above mentioned article for which we wish to thank you.

Very truly yours,

G. C. Chase ep

Research Engineer

EP

INTERNATIONAL BUSINESS MACHINES CORPORATION

GENERAL OFFICES,
270 BROADWAY,
NEW YORK

DIVISIONS:
THE TABULATING MACHINE COMPANY
INTERNATIONAL TIME RECORDING CO.
DAYTON SCALE COMPANY

February 26, 1931.

Mr. L. Leland Locke,
950 St. Johns Place,
Brooklyn, N.Y.

Dear Sir:

In looking over some papers, I came across a short description that was handed to me by a friend of mine from England in the fall of 1928.

As the thing has to do with the historical development of calculating machines, I am attaching a copy which I hope will be at least of interest to you, even though it does not tell you anything that you do not already know.

Very truly yours,

J.W. Bryce

JWB:K
Encl.

2-I. The Galton Quincunx.

Sir Francis Galton, English anthropologist, devised the quincunx which bears his name, to demonstrate that distribution in nature is according to the frequency curves of mathematics.

In this machine steel balls fall in penny slot fashion over round pins, evenly spaced, and drop into compartments below the pins. The heights of the balls in the compartments are the ordinates of a normal frequency curve in this case. The apparatus is rotated through 180 degrees and the balls are again dropped into a restricted space over pins which are regularly spaced as before but triangular in cross-section. The faces of the triangular pins are so set as to deflect all the balls to the left. The curve formed by the balls in this case is a skew normal frequency curve and clearly illustrates the effect of bias on distribution.

Innumerable classes of data may be handled by frequency curves, thus yielding important information. The development of such statistical methods has given an invaluable tool not only to science but also to business and industry.

Built by A Century of Progress. Lent by the Buffalo Museum of Science.

AMM/nm
6/3/36

MUSEUM OF SCIENCE AND INDUSTRY
FOUNDED BY JULIUS ROSENWALD

57TH STREET AND LAKE MICHIGAN

JACKSON PARK · CHICAGO

TELEPHONE: PLAZA 8100

June 10, 1936

Mr. L. Leland Locke
950 St. Johns Place
Brooklyn, New York

Dear Mr. Locke:

Dr. MacMahon has asked me to send you the following description of the Century of Progress exhibit in Mathematics, 2-J, "Computation of Pi":

"It is not difficult to measure the diameter of a circle. But in order to calculate the circumference of a circle, we must employ a number which we designate by the symbol π (a Greek letter pronounced "pie"). To give the circumference of the circle, the diameter is multiplied by π.

π has no exact decimal expression, although its value has been computed to 707 places. As the mathematicians express it, π is "irrational and transcendental." Its value to eight decimal places is 3.14159265.

The method of computation of π shown here is the illustration of a principle discovered by Buffon, a French naturalist (1707-1778). A needle is dropped at random on a flat level floor on which are marked parallel lines. The ratio of the number of times the needle will fall on any one line to the number of times the needle is dropped, will equal the ratio of the length of the needle to π times half the distance between the lines.

We may state Buffon's principle in symbols thus: we call the length of the needle C. We express half the distance between the lines by A; D equals the number of times the needle is dropped and N the number of times it falls across a line. Thus the principle becomes:

$$\frac{N}{D} = \frac{C}{\pi A} .$$

π is the only unknown quantity, and it is equal to $\frac{CD}{AN}$. In this machine we know $\frac{C}{A}$ to be equal to 1.9; π is therefore equal to $1.9\,\frac{D}{N}$. The computation of π thus becomes a simple matter.

In this apparatus the dropping of the needle and the counting of the number of times the needle is dropped and the number of times it falls across a line is done mechanically. The needle is confined inside a box which rotates about a horizontal axis. The box has glass sides so that the visitor can watch the falling of the needle. The floor is made of iron strips separated by thin lines of insulating material. When the needle falls across one of these lines a circuit is completed, and an electric counter registers the fact. The needle is slightly magnetized and is held to the floor while the box is rotated until the floor becomes a ceiling. The needle is then knocked off the ceiling by a tapper and falls through a maze of wire upon the floor again."

With reference to the Century of Progress catalogue, if you do not find it in the New York Public Library, we shall be glad to supply the library with a copy. The catalogues are no longer on sale.

Very truly yours,

N. Mann

N. Mann
Secretary to
Dr. MacMahon

"TABLE OF CONTENTS"

"Wiberg", from: Catalog of National Conservatory (2)

"Herr Wiberg", from: V. 1. of Insurance Cyclopaedia.

"N. Wiberg", from: Ency. of Mathematical Science.

"Wiberg", from: Calculi Simplifie

"Wiberg", from: Bulletin of Societe D'Encouragement Pour L.'Industrie Nationale.

ABSTRACTS FROM CATALOG OF NATIONAL CONSERVATORY.

ARITHMETICAL AND ALGEBRAICAL MACHINES.

4. Machines for Calculating Differences.

WIBERG

Scheutz, father and son, in 1853, and Wiberg in 1863, constructed on different principles machines operating on fourth differences and printing the results of the calculation. Those machines have been used for calculating financial and mathematical tables. Another machine of the same kind conceived by Grant in 1871.

ABSTRACTS FROM CATALOGUE OF NATIONAL CONSERVATORY.

ARITHMETICAL AND ALGEBRAICAL MACHINES.

4. Machines for Calculating Differences.

DR. MARTIN WIBERG

No. 13651 - Photograph of the calculating machine of Dr. Martin Wiberg, from Stokholm; given by him in 1904. (Reproduction to the 1/3).

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ABSTRACT FROM VOLUME 1 OF THE INSURANCE CYCLOPAEDIA, By C. Walford.

HERR WIBERG

The first of these is the invention of Herr Wiberg of Malmo, Sweden. It is a small difference engine of cylindrical form, in which the difference axes are arranged round the circumference of a circule, in place of lying in one plane, as in the machines of Messrs. Babbage and Scheutz. This machine, however, was so much deranged in its transit to the Exhibition, that the jury had no means of testing its mode of action. Herr Wiberg also exhibited a smaller calculating machine, like the other of a circular form, very compactly arranged, and very neatly executed. It was presumed to be for the purpose of multiplication and division; but no precise information could be obtained.

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ABSTRACTS FROM ENCY. OF MATHEMATICAL SCIENCE, Vol. 4, Pt.3.

MACHINES FOR CALCULATING DIFFERENCES.

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The first idea of the differences calculating machines comes from J. H. Muller (237 and dates from 1786. In 1812 Ch. Babbage (238) conceived it anew, and he was the first to realize it in undertaking, in 1823, the construction of a machine operating only on the second differences. Owing to unfavorable exterior circumstances, this construction was not finished and was forsaken completely (239) as early as 1833. A second replica was produced in 1858. Those machines can perform long and numerous calculations with any desirable exactness.

Other differences calculating machines, with a similar mode of action, have been afterwards constructed more easily. We may mention in this respect the differences calculating machines of N. Wiberg (243) and those of G. B. Grant (244). The machine of M. Wiberg specially has given remarkable proofs of its capacity for work (245). L. Bollee the multiplying machine of whom has been mentioned (No. 23, drawings 21 and 22) has drawn the plan of a machine operating on the twenty-seventh differences. If it was realized one would have for making the different tables one needs a more than sufficient approximation (246).

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No. 243 A detailed description of this machine was given by Ch. E. DeLaunay (C.R. Acad.sc.Paris 26 (1863) p 330) see also M. d' Ocagne simplified Calculation, p 86/7.

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Another, Suede Wiberg, has built a machine for differences filling exactly the same place as that of Scheutz, but, owing to a new mechanical means, its dimentions are considerably reduced, while in the Scheutz type there were comparable to a small piano.

This machine Wilberg was presented with a praising note to the Academy of Science in Paris by the astronomer Delaunay. It is composed of 75 metallic disks numbered from 0 to 9 on their periphery and crossed by the same axis, around which they can turn by friction and independently the ones from the others. These 75 disks are divided into 15 groups of 5; each of these groups corresponds to a certain decimal order; in each group the first disk to the left marks the figure of this order for the calculated term, the second the figure of the same order for its first difference, and so on to the fifty which marks the figure of the same order for the fourth constant difference. To read the term obtained we must, going from left to right, extract the figures marked by the disks, taking them five by five beginning rom the first.

The machine Wiberg, like the machine Scheutz, acts successfully one part on the third and first differences, the other on the second difference and the term for the table. It also has a mechanical arrangement in another part of the machine which brings out the first eight figures of the term in relief to impress them on a plate of lead for the stereotype.

In the note of Delaunay can be found a detailed description of the mechanism of this machine, unfortunately without illustrations. Its essential part is an axis parallel to that of the diks which carries 30 indicators. These indicators being placed behind certain teeth joined to the disks push them forward, thereby making the corresponding disks turn around their common axis. A toothed ruler in form of a comb is placed in such a way that the teeth of the 30 disks pushed through its hooks pass freely while the others are made immovable.

The machine has also been used for calculating and printing logarithmical and financial tables which have made evident a certain number of errors in the tables of the same kind previously published.

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ABSTRACTS FROM BULLETIN OF SOCIETE D'ENCOURAGEMENT POUR L'INDUSTRIE NATIONALE

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In 1858 Logarithm tables were so which were calculated and printed by the same machine which became the property of the Dudley Observatory at Albany, U.S. There also exists another model of this machine at the office of the Registrar General of Somerset-House. This second machine was able to calculate and print six hundred and five tables, printed in quarto, and which served as a basis for figuring of interest paid by the Postal Savings Bank in England.

Other machines of the same kind were invented in 1871, one Wiberg, a Swede, and another by Grant, an American. Both of these machines differ quite a little from the first one; they are less clumsy, but these are details on which I do not want to linger.

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Copied from the book of
"English Life Table"

(page cxxxix)

A P P E N D I X .

SCHEUTZ'S CALCULATING MACHINE AND ITS USE IN THE CONSTRUCTION OF THE ENGLISH LIFE TABLE NO. 3.

The following description of the Calculating Machine was sent by the Registrar General to the Exhibition of 1862 for distribution, with specimens of its printed work, of stereotyped plates, and of papier-mâché moulds stamped by its printing apparatus.

The Registrar General would have been glad to send the Machine to be exhibited with the Difference Engine of Mr. Babbage; but it was then in use at the General Registrar Office, and it was a matter of great importance to complete the new Life Tables, for which there was an urgent demand. Upon other grounds the completion of the work was called for.

The first public money was advanced for the Difference Engine of Mr. Babbage in 1823, and it had been so far completed as to show beyond a doubt the practicability of the conception. His Engine was in the Exhibition of 1862; and the first Machine which the Scheutzes, father and son, constructed was exhibited and won the gold medal at the Exhibition of 1855 in Paris. The powers of the Swedish Machine* had been displayed in the production of thirty pages of five-figure logarithms for the numbers from 1,000 to 10,000**; but it had executed no original work of any extent. Now there are, besides the thousands of machines in the clouds of inventors' brains, many ingenious and beautiful machines in exhibitions of no practical use whatever. How can the spectator know whether they will execute genuine work at all? Who can detect their errors or compare the cost of their work with that of other work of the same kind? A watch to look at is sometimes not a watch to go, according to common observation. Which of these classes of works had we in hand? Here were calculating machines in which everybody was interested, which had existed in pieces or in the state of projects, in which money had been invested for nearly forty years, and which in the completed state had hitherto realized none of the expectations which the country naturally entertained; so it did seem that the time had come for substantial work rather than for exhibition and appeals even to legitimate curiosity.

The Machine consists of more than 4,000 pieces, and it is about ten hundredweight***. It had been shaken out of order on its way from the Factory to Somerset House. It might have been injured or destroyed on its journey to or from the Exhibition, and no one would absolutely guarantee its safety there. Under these circumstances the Machine was not exhibited.

So this work was continued uninterruptedly at the General Register Office until it was completed; and I cannot agree with Mr. Babbage, who thinks that it could have been safely carried on in the midst of the crowds of the Exhibition, with incessant interruptions for explanation, and with the possible clang of musical instruments, discordant sounds, or noises in the ears of the operators.

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* This first Swedish Machine was bought by Mr. Rathbone, an American, and presented by him to the Dudley Observatory at Albany. No account has reached us of any work executed by it in America.

** Specimens of Tables calculated, stereo-moulded, and printed by machinery. Longmans, 1857

*** Mr. Bryan Donkin states that Scheutz's Calculating Machine consists of about 4,320 pieces, of which 2,054 are screws, 364 compose the chain, and 902 are other parts of the mechanism. The weight of the Machine (exclusive of case) is by his estimate about 10 cwt.

The Machine required incessant attention. The differences had to be inserted at the proper terms of the various series, checking was required, and when the mechanism got out of order it had to be set right. Of the first watch nothing is known, but the first steam-engine was indisputably imperfect; and here we had to do with the second Calculating Machine as it came from the designs of its constructors and from the workshop of the engineer. The idea had been as beautifully embodied in metal by Mr. Bryan Donkin as it had been conceived by the genius of its inventors; but it was untried. So its work had to be watched with anxiety, and its arithmetical music had to be elicited by frequent tuning and skilful handling, in the quiet most congenial to such productions.

This volume is the result; and thus--if I may use the expression-- the soul of the Machine is exhibited in a series of Tables which are submitted to the criticism of the consummate judges of this kind of work in England and in the world.

If their approving testimony be won, it will be some compensation to the "English workmen," the firm of Messrs. Donkin and the Messrs. Scheutz, for the loss of a medal at the Exhibition of 1862.

The Machine, I should add, was seen by many scientific men at the General Register Office during the Exhibition; and it was made known that it was accessible then, as it is now, to any accredited person, on application to the Registrar General.

General Register Office,
5th August 1864.

W. FARR.

Pascal, Leibnitz, and other mathematicians conceived the idea of performing numerical operations mechanically; and Mr. Babbage invented a calculating machine, of which, for various reasons, he did not complete the construction. It was, however, lucidly described in the Edinburgh Review for July 1834 by Dr. Lardner. The article inspired Mr. Scheutz, a Swede, with enthusiasm in the cause, and he exclaimed, "I also will make a calculating machine." With his son, after many sacrifices, and many years of labour, he succeeded. The machine was brought to England, and its Inventors were received in the most friendly way by Mr. Babbage, who bore open testimony to the originality of the Swedes. A Committee of the Royal Society reported favourably on the machine, and it was exhibited in the rooms at Somerset House, where Mr. Gravatt, a Fellow of the Society, displayed its powers and uses to some of the principal scientific authorities of the kingdom. The machine won a gold medal for its Inventors at the French Exhibition, and was purchased by a liberal American for an Institution in the United States.

Mr. Babbage's account of the labours of the Inventors, and his son's description of the machine containing several hundred different pieces, in the lucid notation of his father, will be found full of interest and instruction. Those two papers, the Edinburgh Review, Weld's History of the Royal Society, the Preface to Scheutz's Specimen Tables, and the Report of the Committee of the Royal Society, give the history of the two machines.

Scheutz's machine had thus passed its preliminary examination satisfactorily.

At that time it appeared to be desirable to construct a new Life Table from the materials accumulated at the General Register Office by the registration of births and deaths in seventeen years (1838-1854), and by the two enumerations of the population of England and Wales in 1841 and 1851.* The Tables for single lives, and the various combinations of joint lives, male and female, involve a great deal of numerical computation; and as it was found that the calculations of the series, thrown into a form which is described elsewhere,** could be performed by the machine, the Registrar General was pleased to bring the matter under the notice of Sir George Lewis, then Secretary of State for the Home Department.

---

*Deaths 6,470,720, with ages distinguished. **Paper presented to the Royal Society, March 17, read April 7, 1859. See Transactions of that year.

And in doing so he pointed out the importance which had been justly attached by the most eminent scientific men of the country, by Her Majesty's Government, and by Parliament, to the machine of Mr. Babbage, for which, though it had not been completed, 17,000l. of money had been granted, besides the money expended by Mr. Babbage himself.* Here was a machine in working order, suggested to its Inventors by the English machine, and which Mr. Scheutz and the Messrs. Donkin offered to construct, with several improvements, for 1,200l;, of which the interest at 5 per cent. was 60l. a year. The Astronomer Royal concurred with the Registrar General in advising Her Majesty's Government to order a new machine; and accordingly the contract was entered into, and a machine was constructed by the Messrs. Donkin from Mr. Scheutz's drawings, superior, as it was reported to the Registrar General, to the first machine.

In constructing a new machine of many pieces, to execute a great number of exact movements, several new tools were required, and the workmen had to be specially instructed. This involved expense, from which the Messrs. Donkin, however, did not shrink.

The machine has been extensively tried, and it has, upon the whole, answered every expectation. But it is a delicate instrument, and requires considerable skill in the manipulation. It consists of a multitude of pieces, and some of these occasionally get deranged, so as to print errors, which can, however, by a due system of checks, be almost invariably detected and rectified. It approaches infallibility in certain respects, but it is not infallible, except in very skilful hands. The weakest point of the machine is the printing apparatus, and that admits of evident improvement.

The machine calculates and prints series of a particular kind, and to the execution of these operations its utility is therefore limited. Its scope is less ambitious than the new analytical machine for which Mr. Babbage abandoned his first invention, as that machine seeks to embrace the whole field of analysis.**

The machine simply performs the operation of addition, but by various expedients the other arithmetical operations can be reduced to this elementary process. Thus the machine, by adding the arithmetical complement of a number to another, virtually produces the same result as by direct subtraction. For subtracting 0°0293838 from 9°8530811 we have 9°8236973. Now the arithmetical complement of 0°0293838, obtained by subtracting it from 10°0000000, is 9°9706162; so the machine adding this to the number gives the following result:

	9°8530811
+arithmetical complement of 0°0293838 =	9·9706162
	19·8236973

It is ten more than that obtained by direct subtraction; and the machine does not print the ten, so it disappears from the result. Subtraction by this simple expedient is performed by the same operations as addition; so by introducing logarithms and their complements, with proper Tables, multiplication and division are also reduced to the same operations as addition.

The calculations for the English Life Table are brought within the compass of the machine at the General Register Office by a method which we will now describe as plainly as possible, and which is based on that of finite differences discovered by Newton.

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* The following statement occurs in Mr. Babbage's "Passages from the Life of a Philosopher:"--"As to the expense actually incurred upon the First Difference Engine, that of the Government was about 17,000l. On my own part and out of my own private resources I have sacrificed upon this and other works of science upwards of 20,000l."

** See a Paper in the Transactions of the British Association.

(page cxlii, continued, and cxliii)

The machine will not calculate the series of double square numbers 1^4; 2^4; 3^4; 4^4; general term x^4; or 1,18,81,256,625,&c. directly by multiplication; but if the differences of these numbers are taken four times, the fourth order of differences will be found constant. They run thus:

(The Function.)

x	xxxx=x^4	$\delta 1$	$\delta 2$	$\delta 3$	$\delta 4$
1	1	15	50	60	24
2	16	65	110	84	24
3	81	175	194	108	
4	256	369	302		
5	625	671			
6	1296				

There is a row of calculating wheels for the Function, and a row for each of the four orders of differences; each wheel being figured 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. These are set. And thus this series may be continued to any extent, by adding the constant numbers of δ^4 to those of δ^3; those under δ^3 to δ^2; those under δ^2 to δ^1; those under δ^1 to 1, 16, &c. called the function, or the series of double squares. The machine performs all these additions, and stereoglyphs the series in a leaden or papier-mâché mould, which serves for stereotyping.

To calculate Interest Tables a series of this kind is required; namely, 1 divided by 1·03, and the quotient again divided by 1·03, &c., so on 100 times. Thus the value of 1l. payable at the end of one year, of 1l. payable at the end of two years, of three years, four years, &c., is found, reckoning the interest of money at 3 per cent. Now the machine will not perform these divisions, and will not therefore give the numbers directly, but it will calculate the logarithms of these numbers by inserting 0·0000000, 5000000 in the function wheels, and constantly adding to it δ^1=9·87162(7),7529484. The machine prints 0·0000000; 9·9871628; 9·9743256; and the other logarithms in pages 6 and 7 of the volume. It will be observed that the bracketed figure (7) is augmented by the machine, and becomes 8. In truth it is followed by a 7; and as 7·7 is nearer to 8·0 than to 7·0, the correction is necessary to make the approximation as near the truth as is possible, with seven decimals. By a very simple arrangement in the setting--that is, by substituting, as above, 5 for the eighth 0 from the decimal point in the first number of the function--the machine effects all the corrections usual in such cases; thus, 7,0; 7,1; 7,2; 7,3; 7,4 are printed as 7, and 7,5; 7,6; 7,7; 7,8; 7,9 are printed 8 in the seventh decimal place.

The book of logarithms gives, in the corresponding numbers, the value of 1l, payable at the end of each year. Thus the value of £1·000 000 payable after the lapse of a year is, ·970,874l.; payable after the lapse of 2 years, ·942,596l.; payable after the lapse of 3 years, ·915,142l; and so on. The sum of 20 of these successive values is the value of an annuity certain for 20 years, and so on for any other number of years. The interest is here taken at 3 per cent. The values for other rates of interest are calculated in the same way by the machine.

There are many series, of which the fourth difference is not constant; yet the error from the neglect of the subsequent orders of differences is so small, that the series is calculated correctly within required degrees of accuracy, by dividing the long series into periods. This is the case with logarithms, which from given sets of four orders of differences can be calculated by the machine.

Such also is the series of logarithms of the probabilities of living a year after any given age. The chance of living a year increases from birth to the age of 12, 13, or 14; and then it decreases at increasing rates, not like interest, however, in simple geometrical ratios, otherwise the series could be calculated by one order of logarithmic differences. Three orders of logarithmic differences are required; and by making the

logarithms of the probability of living a year the first order of differences, the other orders becoming the 2d, 3d, and 4th, we get the series of logarithms corresponding to the numbers out of a given number born, attaining each year of age. The machine has calculated a Table of this kind, showing the numbers living at the end of every quarter of a year of age.

By combining these series for males and females with the interest logarithmic series, and again with each other, the mean duration of life is determined, as well as the value of annuities on one or two lives of the same or of different ages. These Tables have been calculated by the machine, at certain rates of interest.

The art is to shape the formulas and the numerical operations so that they can be executed by the machine.

The following example arranged by Mr. Lewis of this Department displays the method of calculating the Column λl_x Males from the age 20 to 50, and gives some idea of the way in which the Machine has been rendered available in the production of this Volume of Tables.

Referring to the Table of Differences on the next page, it will be seen that the original Differences for the Male ages 20-50 are these:--

Function = λl_{20} = 5.5232361,0000
λp_{20} = $\delta 1$ = 9·9963874,0000
$\delta 2$ = 9·9999196,4155
$\delta 3$ = 0·0000026,4330
$\delta 4$ = 9·9999991,6530

but when they are ready for the machine they are arranged in the following order:

$u_x = \lambda l_{20} = u_{20} = 5{\cdot}5232361,5000$

$\delta^1_{x-1} = \lambda p_{19} = \delta^1_{19} = 9{\cdot}9964712,3645$ } These two differences are taken from those against age 19

$\delta^2_{x-1} = \delta^2_{19} = 9{\cdot}9999161,6355$ }

$\delta^3_{x-2} = \delta^3_{18} = 0{\cdot}0000043,1270$ } These two differences are taken

$\delta^4_{x-2} = \delta^4_{18} = 9{\cdot}9999991,6530$ } from those against age 18

δ^4 being constant remains unchanged.

u_{20} is then placed upon the first or Function row of figure wheels in the machine, δ^1_{19} on the second row, δ^2_{19} on the third row, and so on.

The handle of the machine is then turned, and the effect of the first half-stroke is that the numbers on the third and fifth rows (δ^2 & δ^4) are added to those on the rows immediately above them (δ^1 & δ^3); the second half-stroke adds the new numbers on δ^1 & δ^3 to the numbers on the u_{20} and δ^2, and thus gives u_{21} as the result of a complete forward and backward motion of the machine.

The way in which the machine adds the differences together will be rendered more intelligible by the example here given:

Figure Wheels	Machine as set.	After the forward motion.	After the backward motion
1st row ... u_{20}	= 5·5232361,5000	5·5232361,5000	5·5197135,5000 = u_{21}
2nd row ... δ^1_{19}	= 9·9964712,3645	9·9963874,0000	9·9963874,0000 = δ^1_{20}
3rd row ... δ^2_{19}	= 9·9999161,6355	9·9999161,6355	9·9999196,4155 = δ^2_{20}
4th row ... δ^3_{18}	= 0·0000043,1270	0·0000034,7800	0·0000034,7800 = δ^3_{19}
5th row ... δ^4_{18}	= 9·9999991,6530	9·9999991,6530	9·9999991,6530 = δ^4_{19}

(page cxliv continued)

All that is necessary, therefore, when the differences have been once transferred to the machine, is to turn the handle until the requisite number of values of u_x is obtained.

DESCRIPTION OF THE OBSERVATORY.

METEOROLOGICAL OBSERVATIONS.

January, 1866.

The Swedish Tabulating Machine of G. & E. Scheutz.

It is a well known fact that Mr. Charles E. Babbage was the first to attempt the construction of a Difference Engine; but owing to some misunderstanding between the inventor and the English Government, under whose patronage the work was carried on, it was never completed.

In the Edinburgh Review for July, 1834, Dr. Lardner gave an account of Mr. Babbage's machine, which, coming under the eye of Mr. George Scheutz, an eminent printer at Stockholm, he conceived the idea of building one which should do the work contemplated by Mr. Babbage, but on a totally different plan, as regards the details of the mechanism. After proving the practicability of his ideas in the construction of some models, it was allowed to rest for a year or two. In 1837, Edward, the son, took up the plan, and in conjunction with his father completed a machine of small compass in 1840. This was exhibited before the Swedish Academy of Sciences in 1843. On the certificate of that body, orders to manufacture machines were solicited in different countries, but without success. After numerous failures to secure assistance from the Swedish Government, for the purpose of constructing a large and complete machine, finally in 1851, the Diet with difficulty consented to advance 5,000 rix-dollars, (about $1,500), on condition that the machine should be completed within a year, and that the inventors should give a guarantee to return that sum to the State if it did not prove successful.

Having already expended all their means in the construction of models and tools, they were unable to give the necessary guarantee, and the invention would probably have been abandoned, but for the noble liberality of fifteen members of the Swedish Academy of Sciences, who became responsible for the amount advanced.

The machine was completed in 1853, and performed its work (perfectly). In consideration of the successful issue of the project, and the large sums that had been expended by the inventors, the Diet granted a reward of 5,000 rix-dollars, thus making the total grant 10,000 rix-dollars.

The machine was taken to England and exhibited before the Royal Society of London, and also placed in the great Paris Exposition, where the Gold Medal was unanimously awarded to the inventors.

It was purchased for the Dudley Observatory in 1856, at an expense of $5,000.

This machine was the only one built until 1863, when a duplicate was made for the Registrar General's Office, London, England.

This machine possesses a twofold power, with mechanism appropriate for each; not necessarily connected, though simultaneous and automatic in its entire action. These functions are, first, the production of certain numerical results; second, the conversion of those results into a permanent legible record.

The theory of the machine is based on the mathematical truth, that in any series of numbers, the nth order of differences may be regarded as equal to zero, where n may be any number whatever. To produce such a series by mechanical means, the only condition necessary is that there be as many variable wheels indicating the numbers as we have differences. If n was a very large number, the mechanism would become cumbersome and unwieldly. It is found in practice that for the great majority of useful computations, four orders of differences are sufficient.

This machine is constructed for four orders, and will consequently compute any series, in which the fourth (or any inferior) order of differences are equal.

A portion of the mechanism for printing, is shown at the left end of plate IV. (Litho of Weed Parsons & Co., copy not available). The numbers on the upper row of rings are transferred to the printing part, by means of "the snail" attached to and revolving with the upper rings. This contrivance shown in Fig. 3, has long been used in the striking part of the common eight-day clock.

The result may be stereotyped on strips of lead, or printed on ordinary paper or card-board.

Accounts of Babbage's engine may be found in the Edinburgh Review, July 1834, in Taylor's Scientific Memoirs, v.3, and in the inventor's work, "Passages from the Life of a Philosopher"; short articles on the same in Tomlinson's Cyc. of the Arts and Sciences; Harper's Mag., 1865, Manufacturer and Builder, 1870; Timb's Stories of Inventors, etc. Scheutz's engine is described in "The Swedish Calculating Machine" by Charles Babbage, in "The Manufacturer and Builder" August 1870, and in detail in the British Patent Specifications, Oct. 17, 1854, No. 2216.

5.10.28.

2a
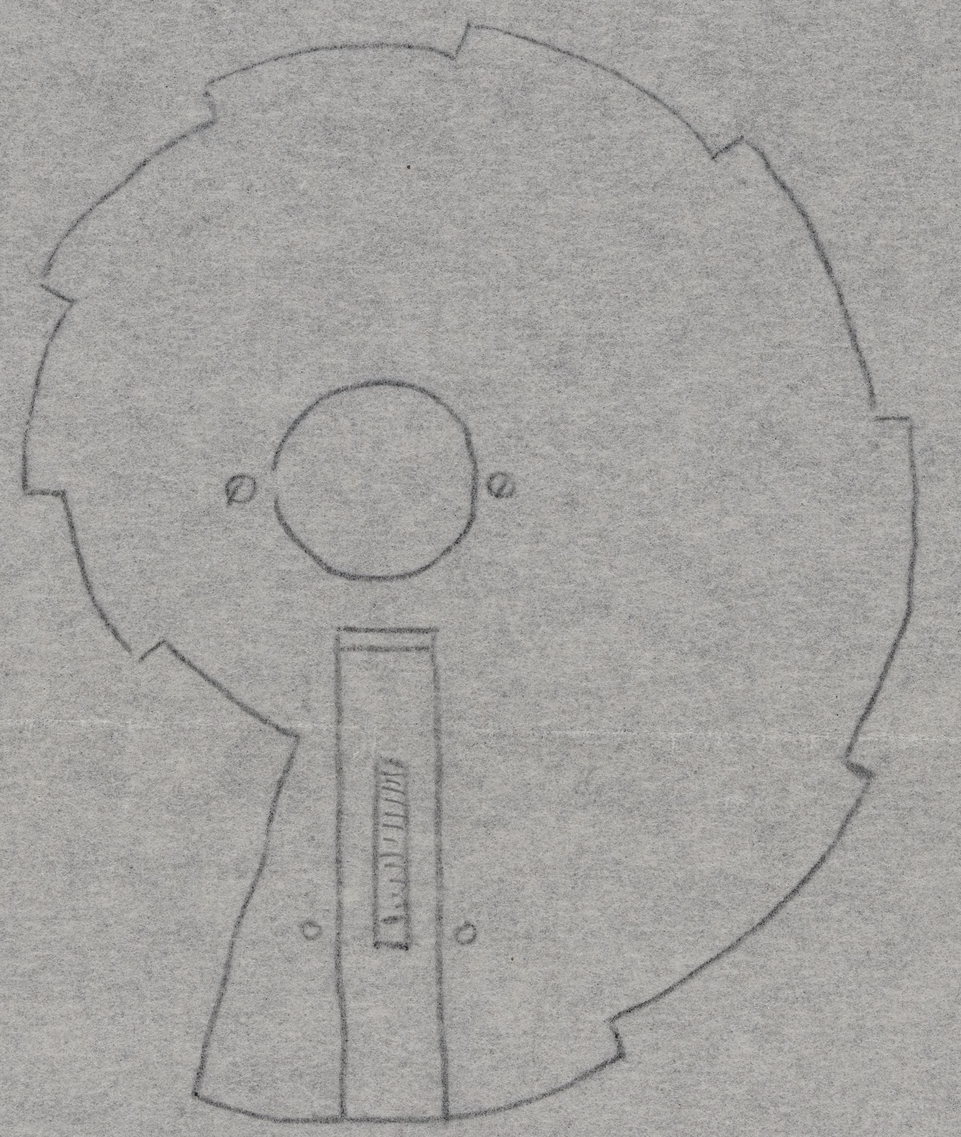
Fig. 3